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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : F17D 3/01

A1

(11) International Publication Number: WO 00/46545

(43) International Publication Date: 10 August 2000 (10.08.00)

(21) International Application Number: PCT/NO00/00025

(22) International Filing Date: 31 January 2000 (31.01.00)

(30) Priority Data:
19990534 5 February 1999 (05.02.99) NO

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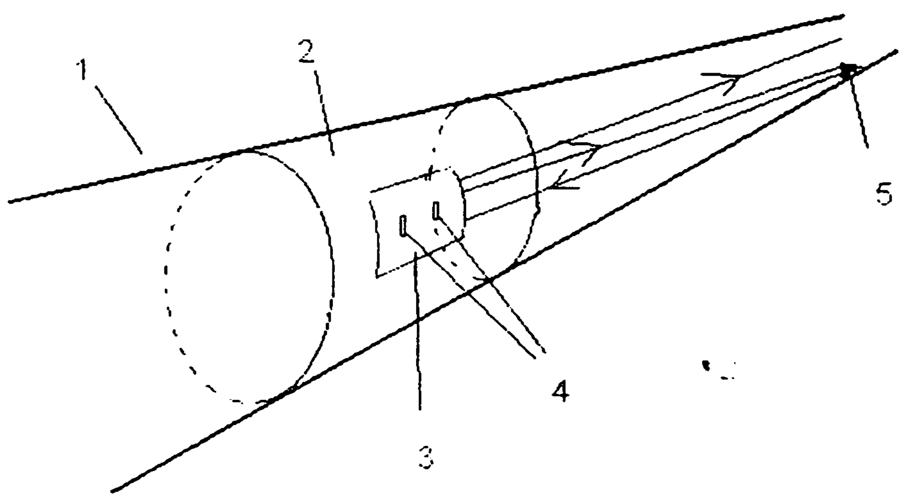
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.
In English translation (filed in Norwegian).

(54) Title: METHOD AND DEVICE FOR MONITORING FLOW PARAMETERS IN A PIPELINE IN ORDER TO REGISTER HYDRATE FORMATION

(57) Abstract



Method for surveillance/monitoring of flow parameters in a pipeline, e.g. for oil or gas, and for detecting formation of hydrate plugs in such a pipeline. The method includes the steps of establishing a wave source/signal transmitter for supplying an electromagnetic wave at one or more frequencies in at least one point of connection to the pipeline, and connecting equipment for registering reflections of such waves as well as equipment for interpretation of said reflections with respect to how the distances between said connecting point and different reflection points vary with time, and to determine the degree of difference between the dielectric constants of the phases between which phase transitions the reflections occur. The invention also concerns a device adapted for performing the methods as well as a utilization of a wave source and a receiver to monitor the flow parameters in a pipeline.

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Method and device for monitoring flow parameters in a pipeline in order to register hydrate formation.

The present invention relates to a method for monitoring flow parameters in a pipeline, e.g. a pipeline for oil or gas, and for detecting hydrate formation in such a pipeline. The invention also relates to a device for performing the method (as well as utilization of a wave source for generating electromagnetic waves in connection with such surveillance).

Background

In the industry concerned with recovery/ production of oil and gas, especially off shore, many challenges are involved in the process of bringing the oil or gas ashore in a convenient way. The most well used technique includes utilizing oil and/ or gas pipes of considerable dimensions, arranged on the sea floor.

This technology is well proven today but not without its problems. Many challenges have to be met in order to arrange the pipeline without complications, as well as maintain problem-free and maintenance free transportation.

The ambient temperature for the pipeline will be quite low in some regions, especially during winter, and may typically be in the range 4 - 7 °C. Temperatures down to -2 °C are known to occur. The product transferred will never be a "pure" product; it will include several components split into two or more phases. Most typically the flow will be a three-phase flow comprising a liquid hydrocarbon phase, a gaseous hydrocarbon phase and varying amounts of water.

In such a flow the water will always react to some extent with different components of the liquid hydrocarbon phase, forming hydrates, and with the temperatures involved some of these hydrates will crystallize to solid particles. This is very inconvenient as the particles tend to be deposited on the inner surface of the pipeline, forming a plug in the pipeline reducing the capacity of the pipeline or plugging it completely.

Many attempts have been made to prevent formation of hydrates ad the subsequent plugging which can occur, most of which involves the addition of hydrate-reducing chemicals to the product flow. This can be an efficient solution, but has the disadvantage of being very costly, so addition of larger amounts of such chemicals than absolutely necessary should be avoided. In addition such chemicals contaminate the product and they may have unwanted environmental effects.

It is, however, not possible to deduce the amounts of chemicals required exactly from mathematical models, as the product composition and therefore the tendency of hydrate formation, varies considerably with time. A continuous monitoring of the product flow in the pipeline would have been a great advantage but has, until now, not been possible to achieve for technological reasons.

Some methods of monitoring have been attempted, e.g. continuous measurement of the pressure at different sites in the pipeline. Drop of pressure would give an indication of hydrate formation, but cannot give an indication of the length and size of the hydrate formed. Measurement of transport capacity as a function of pressure has been used, but the method requires detailed knowledge of the compressibility of the products involved.

Objective

It is therefore an objective with the present invention to obtain a method and a device in relation to the production and transportation of hydrocarbons through a pipeline, which contributes to solving the problems recited, by enabling a continuous monitoring of the production flow in such pipelines over considerable distances.

It is further an objective to perform this by means that do not involve environmental unwanted effects and at the same time are inexpensive in relation to the value of the product flow, so that the overall economy of the process is preserved.

The inventi n

These objectives are obtained by a method as defined by claim 1 and by a device as defined by claim 6.

Further and preferred embodiments of the invention to be described in the following are defined by the dependent claims.

The invention is based on the principle of having a metal pipeline for oil/ gas work as a waveguide for electromagnetic waves. This principle in its general context is known for several applications, especially in radar technology. The present invention deviates from this conventional technology, as the conditions that apply for a pipeline for oil and gas are such that one would not expect that such pipelines would guide electromagnetic waves in a proper manner.

In the traditional sense of waveguides, a minimal transferal loss is desirable independent of the geometry of the construction. The easiest way to obtain this is by using a waveguide with rectangular cross-section. An antenna that gives a linear polarization of the electromagnetic waves has been used to convey the waves to the waveguide. The propagation and orientation of the waves in such a waveguide is well defined even when the waveguide turns around a corner or the like.

The difference in the present situation is significant. Pipelines for oil and gas have a circular cross-section, and will be partly filled with oil, gas or water which give a large and varying attenuation of the signals, a situation very different from one with use of gas or air-filled waveguides. However, it has now been found that with a correct setup it is possible to have such oil and gas pipelines work as a waveguide in the situations relevant for the purpose, i.e. where the primary concern is not to operate at a minimal loss situation, but being capable of registering reflections occurring from different phase transitions in the pipeline. Such reflections are due to differences in the dielectric constant of the phases, and the reflected energy is proportional with the numerical value of the dielectric constant.

A large loss factor in the pipeline is, of course, disadvantageous, as it requires a high number of measurement sites to monitor a large pipeline construction, which would be very expensive. It is therefore preferred to convey the electromagnetic waves to the pipeline by means of antennas that give circularly polarized waves, as these have been found to suffer a considerably less attenuation than linearly polarized waves do in a pipeline with circular cross-section. Choosing a frequency consistent with the dimensions of the pipeline further reduces the loss.

For long propagation distances circularly polarized waves are the only convenient waveform, while for shorter distances linearly polarized waves may also be used.

The installation of the antenna to the pipeline may be done several ways, but for natural reasons it is disadvantageous to position it into the product flow. Such an arrangement would partly make it unavailable for maintenance, but more importantly it would slow down the product flow, which is the contrary to its purpose. It is therefore preferred to have the antenna connected at the outside of the pipeline or as an element encased in the pipeline wall. A preferred embodiment consists of establishing a set of (at least two) "windows" in the pipeline wall, such windows being pressure resistant but transparent for electromagnetic waves, preferably with insignificant loss. Many materials fulfil these requirements, e.g. Plexiglas, which is a preferred material in this context also because it is inexpensive.

A particularly preferred embodiment of the invention consists of prefabricating complete pipeline sections with appropriate diameter, comprising antenna, measuring probes for registering reflected waves and transparent, yet pressure resistant windows in a complete assembled connecting box, equipped externally with the necessary points of connection to any distant external equipment required for monitoring. It is possible, at least some time in the future that all transfer of signals to and from the points of connection may be wireless, and that the required computing means and communication equipment may be fitted into the connecting box.

In order to direct the waves in a given direction along the pipeline from the point of connection, it is necessary to arrange the windows and the antenna in relation to each other and in relation to the frequency or frequencies chosen. This is made such that the signals add to each other in the desired direction and subtract from each other in the opposite direction, according to the general principle of phase controlled directional antennas. Directional antennas as such are well known within the art of radio and radar technology. The mutual position of the windows is simple to calculate for a skilled professional when the concept as such is known.

Use of prefabricated sections with the same inner diameter as the pipeline is also possible for solutions where the antenna is established at the inside of the pipeline wall, e.g. under a protective and electromagnetic transparent layer on the inside of the pipeline wall and preferably in a way allowing the inner cross-section to remain substantially unaffected by the antenna.

Choice of frequency is also a question of great importance in relation to obtaining the optimal combination of highest possible sensitivity for the measurements while at the same time achieving a largest possible reach for the waves. This is a question that can not be completely answered on a theoretical basis alone; a certain degree of experimentation is required. To a certain extent this question involves a conflict of interest, as a very high frequency will have a low attenuation but also a low sensitivity for reflections from points close to the pipeline wall where plugging will first occur. A lower frequency may give a higher sensitivity, but will on the other hand give a higher loss, so that a higher number of measurement points are required. The optimal balancing of these interests can be achieved by a skilled technician performing tests on certain pipelines/ dimensions for relevant product flows.

For a multiphase product flow a "snapshot" registration will be extremely difficult to understand in practice as a very high number of reflection points/ phase transitions will be visible at the same time from any given probe. However, by establishing a systematical pattern of measurements, with fixed short intervals, combined with computerized interpretation of the

signals, it becomes easy to separate the natural "wave fronts" in the product flow from reflections that are statical and represent typical points of plugging in the pipeline.

The equipment utilized to generate the electromagnetic waves for the purpose of the present invention and registering the reflected electromagnetic waves respectively, is conventional radar technology as known from ship navigation systems, defense systems etc. This equipment, however, constitutes no part of the present invention, and is therefore not described in any further detail here.

Drawings

Fig. 1 is a principle drawing of one single point of measurement on a pipeline monitored by the method according to the present invention,

Fig. 2 gives a comparison between theoretical and measured values for different amounts of simulated hydrates, and

Fig 3 shows a plot of two attenuation curves for circularly polarized waves and linearly polarized curves respectively.

Fig. 1 shows a pipeline 1 which includes a prefabricated pipe section 2 comprising a connecting box 3 (known as a directive coupler) for connecting a wave source (not shown) and equipment for registering reflected waves (not shown). Windows 4 are indicated through which waves 5 are conveyed to the inside of the pipeline. The reflection of waves 5 is also indicated from a point where hydrate 6 has been deposited on the inside of the pipeline wall.

Fig. 2 shows the relation between theoretical (dotted lines A,B) and measured values (continuous lines C) of different amounts of hydrates. The hydrates had the shape of thin slices with a composition assumed to be typical in an actual situation. A thin slice means that the hydrate was sliced to a thickness corresponding to between 1/4 to 1/2 of a wavelength (the reason for this being that such slices give a poorer reflection than much larger hydrates). The X-axis shows the relative filling of (one point of) the pipeline cross-section with hydrates, with

a number increasing from 0 to 1, and the y-axis shows the relative magnitude of the signal reflected. The reflection is described in a logarithmic scale (decibel - dB), which is defined as 10 times (deci) the logarithmic ratio between the reflected and the transmitted signal (10 Log_{10} [magnitude reflected signal/ magnitude transmitted signal]). As shown by the drawing, the correlation between calculated and measured values are good.

In fig. 3 the X-axis shows the radar frequency in GHz (10^9 periods/ sec) while the Y-axis gives the attenuation in decibel (dB), defined as 10 times the logarithmic ratio between the magnitude of transmitted signal and the magnitude of the signal at a distance x km from the antenna, (10 Log_{10} [magnitude transmitted signal/ magnitude signal at x km]). The graph labeled $TE_{1,1}$ (transverse electric wave) is linearly polarized (i.e. the electric field is linear) and the graph labeled $TE_{0,1}$ is circularly polarized (i.e. the electric field is circular). Fig. 3 shows that a much lower attenuation (dB/ km) may be obtained by use of circularly polarized waves compared to use of linearly polarized waves, especially at high frequencies. It is therefore preferred to use circularly polarized waves as this allows significantly longer distances between the points of measurements. For the same reason it is also preferrable to use waves with a frequency of at least 5 times the cut-off frequency for the waveguide.

The detailed description given above is only for illustrating and explaining different aspects of the invention. The invention is only limited by the following claims.

Claims

1. Method for surveillance/ monitoring of flow parameters in a pipeline, e.g. for oil or gas, and for detecting formation of hydrate plugs in such a pipeline,
characterized in establishing a wave source/ signal transmitter for supplying an electromagnetic wave at one or more frequencies in at least one point of connection to the pipeline, and connecting equipment for registering reflections of said waves as well as equipment for interpretation of said reflections with respect to how the distances between said connecting point and different reflection points vary with time, and to determine the degree of difference between the dielectric constants of the phases between which phase transitions the reflections occur.

2. Method as defined by claim 1,
characterized in that the connection is made to the outside of the pipeline by means of a sealed connecting box, a so-called directive coupler, from which windows transparent for electromagnetic waves lead into the pipeline, and that the distance between the windows and the arrangement of the wave source is adapted so that the propagation of the waves takes place substantially in one direction along the pipeline.

3. Method as defined by claim 1 or 2,
characterized in that the connection is made by means of a prefabricated element comprising a pipe section of the same inner diameter as the pipeline to be monitored, the element also comprising all necessary connecting means, wave source and equipment for registration of reflected waves.

4. Method as defined by claim 1,
characterized in utilizing a wave source providing circularly polarized waves.

5. Method as defined by claim 1,
characterized in utilizing a wave source providing high frequency radio waves.

6. Device for surveillance/ monitoring of flow parameters in a pipeline, e.g. for oil or gas, and for detecting formation of hydrate plugs in such a pipeline,
characterized in that the device comprises a wave source for supplying an electromagnetic wave at one or more frequencies, means for registering reflections of said electromagnetic wave and means for determination of distance between wave source and the point of reflection.

7. Device as defined by claim 6,
characterized in that it includes a prefabricated element comprising a pipe section (2) with the same diameter as the pipeline to be monitored, and a connecting box (3) sealed tightly to the pipe section, said connecting box comprising all necessary connecting means, wave source and equipment to register reflected waves, while "windows" (4) are provided between said pipe section and said connecting box, said windows being pressure resistant but still transparent for electromagnetic waves, the prefabricated element being adapted to be joined with the pipeline to be monitored so that it will constitute an integrated part of the same.

8. Device as defined by claim 7,
characterized in that said windows (4) are made of Plexiglas.

9. Device as defined by claim 6,
characterized in that said wave source comprises an antenna which provides circularly polarized waves in the pipeline.

10. Device as defined by claim 6,
characterized in that said wave source provides high frequency radio waves.

11. Utilization of a wave source for providing electromagnetic waves as well as a receiver for such waves to monitor flow parameters in a pipeline, e.g. for oil or gas, and for detecting formation of plugs in said pipeline formed e.g. by hydrates, through continuous measurement of reflections of the transmitted waves, hereunder registering of the variation with time between wave source and reflection point.

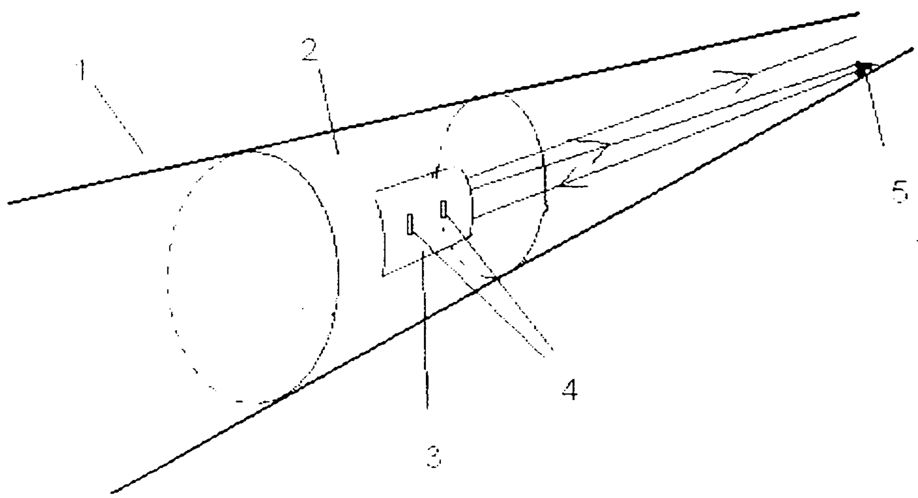

Fig. I

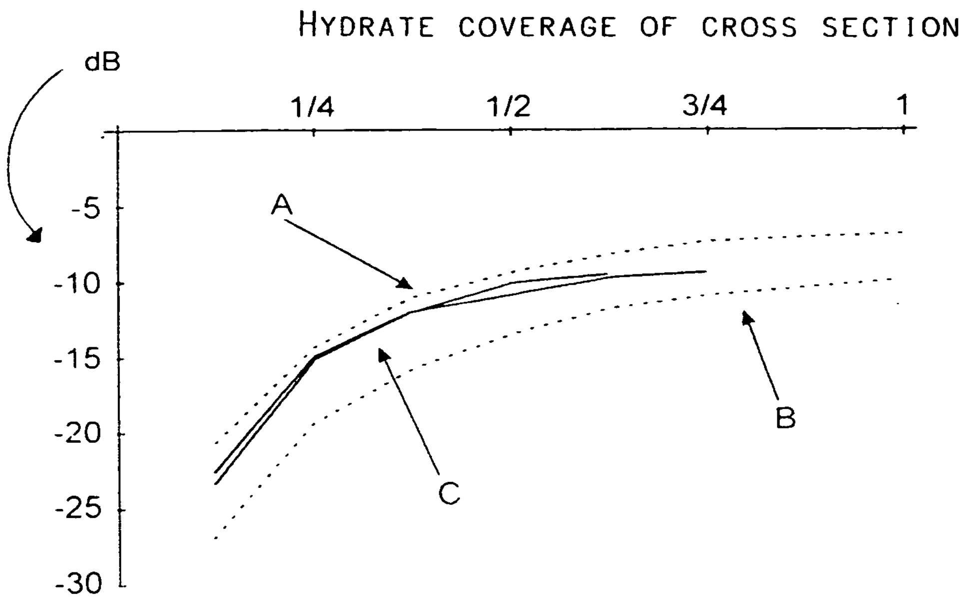
HYDRATE COVERAGE OF CROSS SECTION
dB
1/4
1/2
3/4
1
-5
-10
-15
-20
-25
-30
A
B
C

Fig. 2

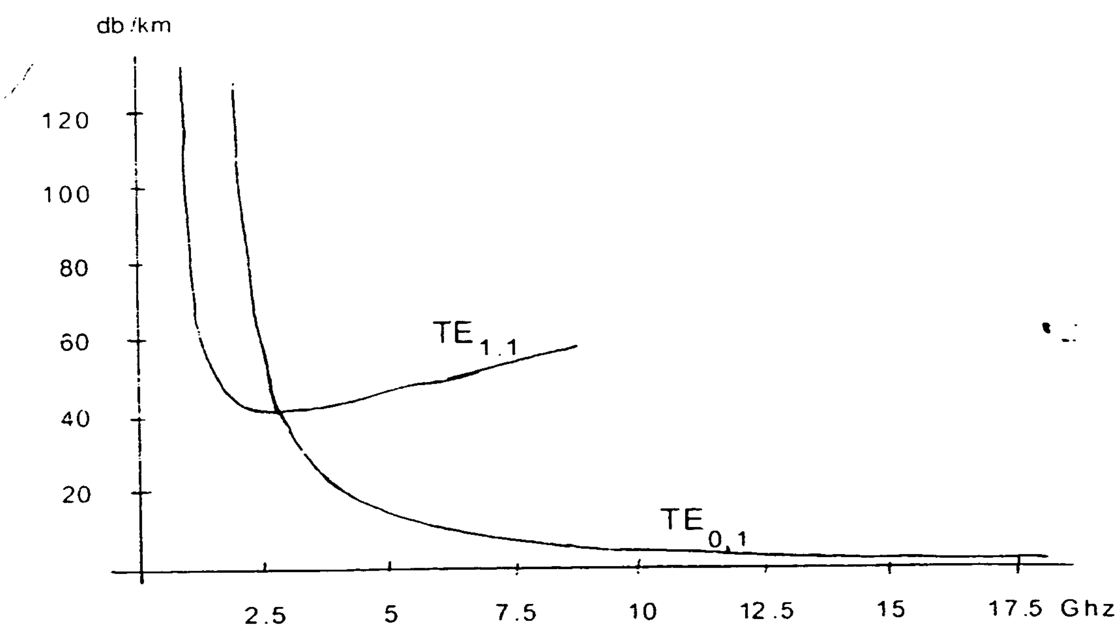
db/km
120
100
80
60
40
20
$TE_{1,1}$
$TE_{0,1}$
2.5
5
7.5
10
12.5
15
17.5 Ghz

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 00/00025

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: F17D 3/01
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: F17D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 2027947 A (FA. LUDWIG KROHNE), 16 December 1971 (16.12.71), figure 1, claim 1 --	1,6,11
A	US 4667515 A (J. FARREN ET AL), 26 May 1987 (26.05.87), figure 5, abstract -- --------	1,6,11

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
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INTERNATIONAL SEARCH REPORT
Information on patent family members

02/12/99

International application No.
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 2027947 A	16/12/71	NONE	
US 4667515 A	26/05/87	AU 585913 B	29/06/89
		AU 5043285 A	12/06/86
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